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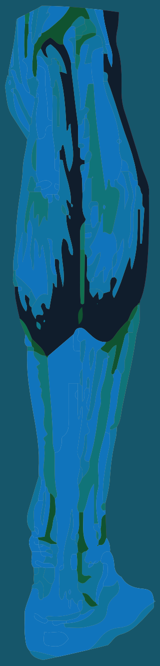
What are the main running-related musculoskeletal injuries? A systematic review

Chapter 3



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Abstract

Background

Musculoskeletal injuries occur frequently in runners and despite many studies about running injuries conducted over the past decades it is not clear in the literature what are the main running-related musculoskeletal injuries (RRMIs).

Objective

The aim of this study was to systematically review studies on the incidence and prevalence of the main specific RRMIs.

Methods

An electronic database search was conducted using EMBASE (1947 to October 2011) MEDLINE (1966 to October 2011), SPORTDiscus (1975 to October 2011), the Latin American and Caribbean Center on Health Sciences Information (LILACS) [1982 to October 2011], and the Scientific Electronic Library Online (SciELO) [1998 to October 2011] with no limits of date or language of publication. Articles that described the incidence or prevalence rates of RRMIs were considered eligible. Studies that reported only the type of injury, anatomical region, or incomplete data that precluded interpretation of the incidence or prevalence rates of RRMIs were excluded. We extracted data regarding bibliometric characteristics, study design, description of the population of runners, RRMI definition, how the data of RRMIs were collected, and the name of each RRMI with their rates of incidence or prevalence. Separate analysis for ultra-marathoners was performed. Among 2,924 potentially eligible titles, eight studies (pooled n=3,500 runners) were considered eligible for the review. In general, the articles had moderate risk of bias and only one fulfilled less than half of the quality criteria established.

Results

A total of 28 RRMIs were found and the main general RRMIs were medial tibial stress syndrome (incidence ranging from 13.6% to 20.0%; prevalence of 9.5%), Achilles tendinopathy (incidence ranging from 9.1% to 10.9%; prevalence ranging from 6.2% to 9.5%), and plantar fasciitis (incidence ranging from 4.5% to 10.0%; prevalence ranging from 5.2% to 17.5%). The main ultra-marathon RRMIs were Achilles tendinopathy (prevalence ranging from 2.0% to 18.5%) and patellofemoral syndrome (prevalence ranging from 7.4% to 15.6%).

Conclusion

This systematic review provides evidence that medial tibia stress syndrome, Achilles tendinopathy, and plantar fasciitis were the main general RRMIs, whilst Achilles tendinopathy and patellofemoral syndrome were the most common RRMIs for runners who participated in ultra-marathon races.

Introduction

Running is one of the most popular physical activities enjoyed by people around the world[1] and the number of runners has grown substantially over the past decades. People seeking a healthier lifestyle through weight control and improved exercise capacity frequently choose running, as this has been considered to be of low cost and can be easily implemented.[2] More importantly, running has many beneficial effects including a reduction of risk factors for cardiovascular disease.[3] Despite these health benefits, running injuries are common, with incidence rates ranging between 18.2% and 92.4%,[4-6] or 6.8 to 59 injuries per 1,000 hours of exposure to running.[7-12] This large variation in incidence rates of running injury may be explained by the difference in the subjects' characteristics, as well as the definitions of running-related musculoskeletal injuries (RRMIs), which differ between studies.[5]

Studies have been conducted to identify what are the most common injuries among runners.[2,6,8,12-19] However, because of a large heterogeneity in the studies performed (e.g., RRMI definition, type of runners, injury classification, and/or diagnosis), the literature does not provide a clear direction on the most incidental and/or prevalent RRMIs. In the prevention and rehabilitation of RRMIs, the identification of the main injuries is important as this can direct physicians, coaches, healthcare professionals, and researchers to channel their resources on how to develop specific prevention and intervention strategies to decrease both the incidence and severity of these injuries. To our knowledge, there is no systematic review that summarises the incidence and prevalence estimates of each RRMI. Therefore, the aim of this study was to systematically review the literature on the incidence and prevalence of RRMIs.

Methods

Eligibility criteria and study selection

An electronic database search was conducted on EMBASE (1947 to October 2011), MEDLINE (1966 to October 2011), SPORTDiscus (1975 to October 2011), Latin American and Caribbean Center on Health Sciences Information (LILACS) [1982 to October 2011], and Scientific Electronic Library Online (SCIELO) [1998 to October

2011] databases, with no limits of language or date of publication. The date of the last search was October 2011 and the search strategy, terms, and operands used are presented in Table 3.1. We included articles related to RRMIs that clearly described or diagnosed running-related injuries with their rates or frequency distribution (incidence or prevalence) of each RRMI. The inclusion criteria were prospective cohort studies and non-intervention groups from clinical trials related to the prevention of running-related injuries that included only runners without injury in the selection process of the study (for incidence estimates); and prospective, cross-sectional, and retrospective studies that included injured and uninjured runners in the selection process of the study (for prevalence estimates).

We excluded articles that (i) included only injured runners as their sample; (ii) described only the injury type (e.g., tendinopathy) or anatomical region (e.g., knee injury) but without a clear definition of the injury (e.g., Achilles tendinopathy); (iii) do not provide quantitative data regarding the injuries rate or frequency distribution (incidence or prevalence) of each RRMI or incomplete data (i.e., we excluded articles that did not present incidence and/or prevalence estimates of all RRMIs) that precluded interpretation of what would be the most frequent RRMIs in runners; and (iv) described the running-related injuries together with other sports injuries in which the RRMIs could not be distinguished. The screening of eligible studies was performed in three steps: (i) screening the titles; (ii) screening the abstracts; and (iii) screening the full texts. Each step was performed by two independent reviewers (LCHJ and Aline Carla Araújo de Carvalho) and, in case of disagreement between the reviewers, a final arbitration was performed by a third independent reviewer (ADL).

Data extraction and data analysis

Data from each article were extracted by one reviewer who extracted the following information: first author, year of publication, study design, description of the population of runners (e.g., marathon or half-marathon runners), definition of RRMI, how the data of RRMIs were collected, and the incidence or prevalence rates of the RRMIs. Information regarding incidence was extracted from prospective studies that evaluated uninjured runners who were followed over the study time period (new injuries analysis).

Table 3.1 Search strategies for each database

EMBASE		MEDLINE		SPORTDiscus		LILACS		SCIELO	
Search number	Search term	Search number	Search term	Search number	Search term	Search number	Search term	Search number	Search term
1	Marathon runner	1	Marathon runner	1	Running injuries	1	Running AND injur*	1	Running AND injuries
2	Running	2	Running	2	Limit: journal				
3	Treadmill exercise	3	Treadmill exercise	3	Limit: thesis				
4	Jogging	4	Jogging	4	1 AND 2 AND 3				
5	OR/1-4	5	OR/1-4						
6	Sport injury	6	Sport injury						
7	Limit: humans	7	Limit: humans						
8	5 AND 6 AND 7	8	5 AND 6 AND 7						
Results[a]									
544		**670**		**1666**		**30**		**14**	

[a] Total number of articles retrieved for each database.
LILACS = Latin American and Caribbean Center on Health Sciences Information; SciELO = Scientific Electronic Library Online.

Information regarding prevalence was extracted from retrospective and/or cross-sectional studies[20] that did not include injured runners only in the subject population. As the articles included in this review consisted of prospective, retrospective, cross-sectional, and clinical trials, we were unable to find any validated published tool that could be applied to evaluate the risk of bias with such diversified research designs. Therefore, the authors of this review developed the criteria for assessing the risk of bias of the articles based on the criteria used in three previous studies.[5,21,22] Among them, one aimed to review the overall incidence of running injuries,[5] another study proposed a tool for assessing the risk of bias of prevalence studies on low back pain,[22] and the last study suggested a methodological guide for conducting studies aimed to evaluate the rate or frequency distribution of overuse sports injuries.[21]

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The criteria for assessing the risk of bias were: (1) definition of RRMIs described in each article (yes/no); (2) studies with prospective designs that presented incidence data, or studies with prospective and cross-sectional designs that presented prevalence data (yes/no); (3) description of the population of runners or the type of runners (e.g., marathon runners or half-marathon runners) that participated in the study (yes/no); (4) whether the process of inclusion of runners in the study was at random (i.e., not by convenience) or the data collection was performed with the entire target population (yes/no); (5) data analysis was performed with at least 80% of the runners included in the study (this criterion was applied only to studies with prospective design and assessed as 'yes' or 'no'); (6) whether the data regarding the injuries were self-reported by the runners of the study or by a healthcare professional (yes/no); (7) whether the same mode of data collection (e-mail, telephone, interview, etc.) was used (yes/no); (8) whether the diagnosis was conducted by medical doctors (yes/no); (9) follow-up period of at least six months for prospective studies and retrospective data collection of up to 12 months for the retrospective studies (this criterion did not apply to cross-sectional studies and was assessed by 'yes' or 'no'); and (10) incidence or prevalence rates of each RRMI expressed by some ratio that represents both the number of injuries as well as the exposure to running (e.g., RRMI/1,000 hours of running exposure, and this criterion was assessed by 'yes' or 'no'). The detailed description of each criterion and how the assessment of risk of bias was performed are presented in appendix 1 (see the Supplemental Digital Content*).

* The Supplemental Digital Content can be found at:
http://link.springer.com/article/10.1007/BF03262301#SupplementaryMaterial

Due to the heterogeneity of study designs, we did not pool the data for analysis. The analysis was conducted descriptively and the data were presented as frequency distributions of incidence or prevalence of each RRMI, and were expressed as percentages. We decided to separately analyse the articles related to ultra-marathon races because these studies were only conducted during races that lasted from 5 to 8 days, and we believe that the injury data have different characteristics to those studies that captured the RRMIs with a defined period of time. We used two criteria to rank the most frequent RRMIs observed in this review: (i) the number of articles that reported each RRMI, because it means that the injury was frequently found among the populations of the different running injury studies; and (ii) the highest incidence estimates for each general RRMI and the highest prevalence estimates for each ultra-marathon RRMI found among studies of this review.

Results

A total of 2,924 articles were retrieved from the five databases. Among them, 540 were duplicated. After screening of the title, abstracts, and full texts, if appropriate, only eight studies met the criteria for inclusion. Figure 3.1 shows the inclusion process for this review. Eight studies with 3,500 runners were included in this analysis. Two were prospective cohort studies,[10,23] one was a clinical trial,[24] two were retrospective cohorts,[25,26] and three were cross-sectional studies.[27-29] Five of them evaluated the incidence[10,23,24] (Table 3.2) or prevalence[25,26] (Table 3.3) of the general RRMIs, and three studies[27-29] captured the RRMIs during ultra-marathon races (Table 3.4). The control group of the clinical trial[24] was included in this systematic review because the participants of this group did not receive any intervention, and the inclusion criteria of the runners from this specific trial were not restrictive and were very similar to the other observational studies that were included. In assessing the risk of bias of these eight articles, of a total possible score of 10, the range of the overall score was 4 to 8. Table 3.5 details the score and assessment criterion on the risk of bias for these eight studies.

A total of 28 different RRMIs were reported in these eight studies. For the estimation of the incident rate of the RRMIs, the capturing period for the three studies was 12 months. For the prevalence, the retrospective periods were 12 and 24 months, respectively. The

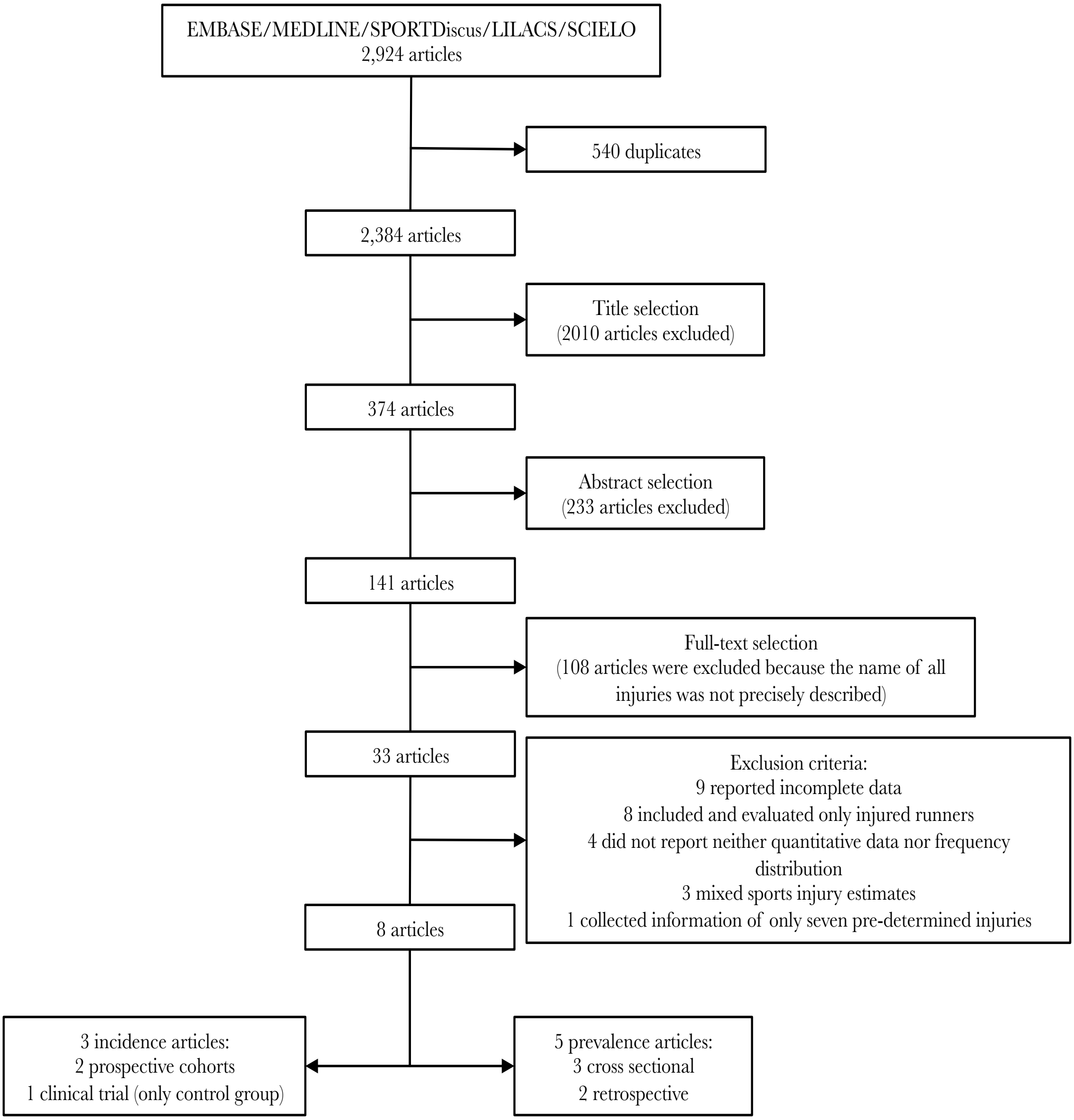

Figure 3.1 Flowchart of the inclusion process of the articles in the systematic review. LILACS = Latin American and Caribbean Center on Health Sciences Information; SCIELO = Scientific Electronic Library Online.

Table 3.2 Incidence rates of running-related musculoskeletal injuries (RRMI)

Study, year	Study design (follow-up period in months)	Population	Musculoskeletal injury definition	Injuries data collection	RRMIs	Incidence % (n)
Pileggi et al.,[23] 2010	Prospective cohort (12 months)	18 amateur runners. Running at least 5 times/week and runners aimed to run 50 km/week.	Interference in training: grade I (no interruption); grade II (volume reduction); grade III (interruption for at least 2 weeks). Symptoms duration: acute (until 2 weeks); Sub-acute (2 to 6 weeks); Chronic (more than 6 weeks)	Injuries were reported by the runners by telephone or in person and evaluated by a physician	Patellar tendinopathy	22.7 (5)
					Medial tibial stress syndrome	13.6 (3)
					Iliotibial band syndrome	9.1 (2)
					Achilles tendinopathy	9.1 (2)
					Tibial stress fracture	9.1 (2)
					Retrochanteric bursitis	9.1 (2)
					Calf muscle injury	4.5 (1)
					Hip adductor muscle injury	4.5 (1)
					Iliac crest stress fracture	4.5 (1)
					Infrapatellar bursitis	4.5 (1)
					Plantar fasciitis	4.5 (1)
Jakobsen et al.,[24] 1994	Clinical trial[a] (12 months)	20 marathon runners	Any injury of the musculoskeletal system that was sustained during running and prevented training or competition	Injuries were reported by the runners in a questionnaire and evaluated by a physician	Medial tibial stress syndrome	20.0 (4)
					Sprain ankle joint	15.0 (3)
					Achilles tendonitis	10.0 (2)
					Muscle fibre rupture	10.0 (2)
					Runner's knee[b]	10.0 (2)
					Plantaris fasciitis	10.0 (2)
					Sprain knee joit	5.0 (1)
					Costal fracture	5.0 (1)
					Other	20.0 (4)
Lyshoml and Wiklander,[10] 1987	Prospective cohort (12 months)	60 runners: 28 long-distance/marathon; 13 middle distance; 19 sprinters	Injuries that markedly hampered running training or competition for at least 1 week	Injuries were reported by the runners in a running diary and evaluated by a physician	Medial tibial stress syndrome	14.5 (8)
					Hamstrings strain	10.9 (6)
					Ankle sprain	10.9 (6)
					Achilles tendinitis	10.9 (6)
					Hamstrings tendinitis	7.3 (4)
					Plantar fasciitis	7.3 (4)
					Patellofemoral pain	5.5 (3)
					Patellar tendinopathy	5.5 (3)
					Low back pain	5.5 (3)
					Hip trochantheritis	3.6 (2)
					Hip adductor tendinitis	3.6 (2)
					Tibialis posterior tendinitis	3.6 (2)
					Gastrocneminus strain	3.6 (2)
					Toe tendinitis	3.6 (2)
					Iliotibial tract syndrome	1.8 (1)
					Metatarsalgia	1.8 (1)

[a] Only data from the control group is presented.
[b] It was not possible to identify in the article the specific injury related to the term "runner's knee".
RRMIs = running-related musculoskeletal injuries.

Table 3.3 Prevalence rates of running-related musculoskeletal injuries

Study, year	Study design	Population	Musculoskeletal injury definition	Injuries data collection	RRMIs	Prevalence % (n)
McKean et al.,[26] 2006	Retrospective (12 months)	2825 runners of a race where each runner ran around 20 km	An event that affected the athlete's ability to train or race	The study registered injuries reported by the runners, physician or another health professional in a survey	Plantar fasciitis	17.5 (495)
					Patellar tendinitis	12.5 (353)
					Hamstrings tendinopathy	12.5 (353)
					Iliotibial band syndrome	10.5 (297)
					Achilles tendinopathy	9.5 (268)
					Ankle sprain	9.5 (268)
					Medial tibial stress syndrome	9.5 (268)
					Patellofemoral syndrome	5.5 (156)
					Stress fracture	4.5 (127)
					Meniscal injury	3.5 (99)
					Other tendonitis	5.0 (141)
Jacobs and Berson,[25] 1986	Retrospective (2 years)	451 runners of a 10 km race	Rate injuries on a scale of 1 to 4 at various sites on the basis of symptoms, with 4 meaning that pain prevented all running until the injury was improved; and if runner had sought professional medical care	Injuries were reported by the runners in a questionnaire	Knee pain	21.4 (45)
					Ankle pain	12.4 (26)
					Medial tibial stress syndrome	9.5 (20)
					Hamstrings injury	6.7 (14)
					Achilles tendinitis	6.2 (13)
					Calf pain	6.2 (13)
					Plantar fasciitis	5.2 (11)

RRMIs = running-related musculoskeletal injuries.

Table 3.4 Prevalence rates of running-related musculoskeletal injuries during ultra-marathon races

Study, year	Study design	Population	Musculoskeletal injury definition	Injuries data collection	RRMIs	Prevalence % (n)
Scheer and Murray,[29] 2011	Cross-sectional	69 ultra marathon runners of a 5 days race	NR	Injuries were reported and evaluated by a medical team of a ultra marathon race with 3 general practitioners and 4 nurses	Patellofemoral pain syndrome	9.1 (9)
					Ankle inversion injury	5.1 (5)
					Trochanteric bursitis	3.0 (3)
					Achilles tendinopathy	2.0 (2)
					Ankle dorsiflexors tendinopathy	1.0 (1)
					Quadriceps muscle pain	1.0 (1)
					Tibialis anterior muscle pain	1.0 (1)
Fallon,[27] 1996	Cross-sectional	32 ultra marathon runners of a 5 to 8.5 days race	NR	Injuries were reported by the runners during the race and evaluated by a physician	Retropatellar pain syndrome	15.6 (10)
					Achilles tendinitis	7.8 (5)
					Anterior compartment tendinitis	7.8 (5)
					Extensor digitorum tendinitis	7.8 (5)
					Medial tibial stress syndrome	7.8 (5)
					Patellar tendinitis	6.3 (4)
					Anterior compartment pain	6.3 (4)
					Iliotibial band syndrome	4.7 (3)
					Quadriceps strain/tear	4.7 (3)
					Back muscle strain	3.1 (2)
					Peroneal tendinitis	3.1 (2)
					Non-specific knee pain	3.1 (2)
					Grater trochanteric bursitis	3.1 (2)
					Extensor hallucis longus tendinitis	3.1 (2)
Hutson,[28] 1984	Cross-sectional	25 ultra marathon runners of a 6 days race	Injuries sufficiently severe to impair their performance	Records were kept of the injuries sustained and of the consultations with the doctor and physiotherapist	Foot dorsiflexors tendinitis	29.6 (8)
					Achilles tendinitis	18.5 (5)
					Patellar tendinitis	18.5 (5)
					Psoas bursitis	11.1 (3)
					Medial tibial stress syndrome	11.1 (3)
					Patellofemoral syndrome	7.4 (2)
					Gastrocnemius strain	3.7 (1)

NR = not reported; RRMIs = running-related musculoskeletal injuries.

Table 3.5 Risk of bias assessment of the studies

Study, year	Risk of bias assessment of the studies										
	1[a]	**2**[a]	**3**[a]	**4**[a]	**5**[a]	**6**[a]	**7**[a]	**8**[a]	**9**[a]	**10**[a]	**Score**
Incidence											
Pileggi et al.,[23] 2010	+	+	+	-	+	+	-	+	+	-	7/10
Jakobsen et al.,[24] 1994	+	+	+	-	+	+	+	+	+	-	8/10
Lyshoml and Wiklander,[10] 1987	+	+	+	-	+	+	+	+	+	-	8/10
Prevalence											
Scheer and Murray,[29] 2011[b]	-	+	+	+	NA	+	+	+	NA	-	6/8
McKean et al.,[26] 2006	+	-	+	-	NA	+	-	-	+	-	4/9
Fallon,[27] 1996[b]	-	+	+	-	NA	+	+	+	NA	-	5/8
Jacobs and Berson,[25] 1986	+	-	+	+	NA	+	+	-	-	-	5/9
Hutson,[28] 1984[b]	+	+	+	+	NA	-	-	-	NA	-	4/8

[a] Method for assessing risk of bias. (1) Definition of RRMI clearly described. (2) Prospective design for incidence or prevalence of injury or cross-sectional design for prevalence of injury. (3) Runners description or type of runners described. (4) The process of inclusion of runners was at random or the data collection was performed with the entire target population. (5) Data analysis was conducted in at least 80% of the runners included. (6) Data collected directly by the runners or injuries evaluation was carried out by any health professional. (7) Same mode of data collection (e-mail, telephone, interview, etc.) was used. (8) If the diagnosis was conducted by medical doctors. (9) Follow-up period for at least 6 mo for prospective studies and retrospective studies conducted of up to 12 mo. (10) RRMIs reported by a ratio expressing the number of injuries and the exposure to running.

[b] Studies conducted only during ultra-marathon races.

NA = not applicable; RRMIs = running-related musculoskeletal injuries. + indicates yes: low risk of bias; - indicates no: high risk of bias.

studies that captured the RRMIs during ultra-marathon races varied the race days from 5[29] to 6[28] or 5 to 8 days.[27] The most frequent reported RRMIs differ between non-ultra-marathon runners and ultra-marathoners. Table 3.6 shows the 21 general RRMIs. Table 3.7 presents the 15 RRMIs reported during ultra-marathon races. The highest incident rate of RRMIs was patellar tendinopathy (22.7%). The most prevalent general RRMI was plantar fasciitis (17.5%) and the most prevalent RRMI during ultra-marathon races was ankle dorsiflexors tendinopathy (29.6%).

The most frequently general RRMIs reported were medial tibial stress syndrome (incidence rate ranging from 13.6% to 20.0%; prevalence rate of 9.5%), Achilles tendinopathy (incidence rate ranging from 9.1% to 10.9%; prevalence rate ranging from 6.2% to 9.5%), and plantar fasciitis (incidence rate ranging from 4.5% to 10.0%; prevalence rate ranging from 5.2% to 17.5%). For RRMIs sustained during ultra-marathon races, the most frequently reported were Achilles tendinopathy (prevalence rate ranging from 2.0% to 18.5%) and patellofemoral syndrome (prevalence rate ranging from 7.4% to 15.6%).

Discussion

This was the first systematic review on the incidence and prevalence rates of RRMIs reported during distance running training or races. The eight articles included in this review differ in the study designs (prospective cohorts, one clinical trial, retrospective, and cross-sectional studies), injury definitions, and type of runners studied. A total of 28 RRMIs were reported, and the most frequently general RRMIs reported were medial tibial stress syndrome, Achilles tendinopathy, and plantar fasciitis; and the main ultra-marathon injuries were Achilles tendinopathy and patellofemoral syndrome. In general, these studies presented a moderate risk of bias.

Most of the injuries observed in this study are related to overuse, i.e., overloading the musculoskeletal structures of the runners.[15,30] The RRMIs were predominantly below the knee (two of them located on the foot and ankle, one located on the lower leg, and one located on the knee). This is consistent with the literature that shows the region below the knee as the most common anatomical location of RRMIs.[2,5,18,31,32]

Table 3.6 Incidence and prevalence of running-related musculoskeletal injuries (incidence pooled n=98 runners; prevalence pooled n=3276 runners)

RRMI	Incidence (%)[a]	Number of articles that reported RRMI[b]	Prevalence (%)[a]	Number of articles that reported RRMI[b]
Medial tibial stress syndrome	13.6 to 20.0	3/3	9.5	2/2
Achilles tendinopathy	9.1 to 10.9	3/3	6.2 to 9.5	2/2
Plantar fasciitis	4.5 to 10.0	3/3	5.2 to 17.5	2/2
Patellar tendinopathy	5.5 to 22.7	2/3	12.5	1/2
Ankle sprain	10.9 to 15.0	2/3	9.5	1/2
Iliotibial band syndrome	1.8 to 9.1	2/3	10.5	1/2
Hamstring muscle injury	10.9	1/3	6.7	1/2
Tibial stress fracture	9.1	1/3	4.5	1/2
Hamstring tendinopathy	7.3	1/3	12.5	1/2
Patellofemoral syndrome[c]	5.5	1/3	5.5	1/2
Gastrocnemius muscle injury	3.6 to 4.5	2/3	-	-
Retrochanteric bursitis	9.1	1/3	-	-
Low back pain	5.5	1/3	-	-
Costal fracture	5.0	1/3	-	-
Knee sprain	5.0	1/3	-	-
Hip adductor muscle injury	4.5	1/3	-	-
Iliac crest stress fracture	4.5	1/3	-	-
Infrapatellar bursitis	4.5	1/3	-	-
Hip adductor tendinipathy	3.6	1/3	-	-
Tibialis posterior tendinopathy	3.6	1/3	-	-
Meniscal injury	-	-	3.5	1/2

[a] Data are presented in percentages or percentage ranges where specified. [b] Number of articles that reported RRMIs refers to the number of articles that reported the incidence (total of incidence articles = 3) or prevalence (total of prevalence articles not conducted in ultra-marathon races = 2) of each RRMI. [c] Represents patellofemoral syndrome and patellofemoral pain. RRMIs = running-related musculoskeletal injuries.

Table 3.7 Prevalence of running-related musculoskeletal injuries sustained during ultra-marathon races (prevalence pooled n=126)

RRMI	Prevalence (%)[a]	Number of articles that reported the RRMI[b]
Achilles tendinopathy	2.0 to 18.5	3/3
Patellofemoral syndrome[c]	7.4 to 15.6	3/3
Ankle dorsiflexors tendinopathy	1.0 to 29.6	2/3
Patellar tendinopathy	6.3 to 18.5	2/3
Medial tibial stress syndrome	7.8 to 11.1	2/3
Quadriceps muscle injury	1.0 to 4.7	2/3
Trochanteric bursitis	3.0 to 3.1	2/3
Psoas bursitis	11.1	1/3
Extensor digitorum tendinopathy	7.8	1/3
Ankle sprain	5.1	1/3
Iliotibial band syndrome	4.7	1/3
Gastrocnemius muscle injury	3.7	1/3
Extensor hallucis longus tendinopathy	3.1	1/3
Peroneal tendinopathy	3.1	1/3
Tibialis anterior muscle injury	1.0	1/3

[a] Data are presented in percentages or percentage ranges where specified. [b] Number of articles that reported RRMIs refers to the number of articles that reported the prevalence (total of prevalence articles conducted in ultra-marathon races = 3) of each RRMI. [c] Represents patellofemoral syndrome, patellofemoral pain syndrome and retropatellar pain syndrome. RRMIs = running-related musculoskeletal injuries.

3

Medial tibial stress syndrome (also known as shin splints) was reported in all three prospective studies and ranked first in two of the studies and second in the other. There are two possible reasons why medial tibial stress syndrome is so frequent among runners. The first is during the landing and propulsion of running; repetitive contraction of the posterior tibial, soleus, and/or flexor digitorum longus muscles would generate excessive stress on the tibia, resulting in inflammation from insertion of the periosteal.[33-37] The second is the insufficient capacity for bone remodelling constituted by repetitive and persistent stress on the tibia caused not only by the muscle contraction but also on the vertical ground reaction during the landing phase in running.[34,38] A prospective cohort study on running injuries also indicated that a greater knee varus, the frequency of change in different types of running shoes, and interval training are the three potential risk factors for shin running injuries.[12] However, it must be stressed that direct cause-effect relationships of this kind of RRMI has yet to be determined.[5,39]

The excessive loading during physical activity has been considered to be the main stimulus for the development of the tendinopathies.[40] Repetitive stimuli load the tendon beyond its physiological tolerance leading it to degeneration.[41] This excessive loading generated in the gastrocnemius and soleus muscles during running may predispose to the development of Achilles tendinopathy in runners.[42] A retrospective study showed that running on sand surfaces and running races from 1,500 m to 5 km increased the risk of Achilles tendinopathy.[14] It might be because running on sand surface demands excessive push off and runners normally prefer forefoot running for shorter races as this will decrease the landing time and increase the running velocity. Nonetheless, high quality, prospective cohort studies are needed to confirm these findings.[39]

The patellar tendon is exposed to high and repetitive eccentric loads of the quadriceps femoris muscle during running, which may explain the high injury rate of patellar tendon in runners.[43] Indeed, patellar tendinopathy was frequently reported in RRMIs among amateur runners who aimed to run between 20 and 50 km per week.[23,26] However, it is interesting to note that patellar tendinopathy is not common among marathon runners.[24] It is not clear if running experience or adaptation is a protective factor for the onset of tendinopathy, but from the results of the ultra-marathon races, the acute onset of the tendinopathy is very likely to appear when the runners are subjected to consecutive running from 5 to 8.5 days.[27,28]

Plantar fasciitis is considered by healthcare professionals to be one of the most common injuries of the foot,[44] and it is characterised by a degenerative process of the plantar fascia[45] that causes pain on the medial calcaneus tubercle during weight bearing.[46] The failure of the fascia on supporting the loads applied to the body is commonly described as the mechanism of plantar fasciitis.[47] Indeed, plantar fasciitis was the most prevalent RRMI among master runners.[26] During the heel strike phase of running, the heel is the first contact point that has to absorb the impact of up to three times the total body weight.[48] The ability to absorb and transmit this impact depends on the resilience of the plantar fascia, the plantar fat pad, and the intrinsic muscles of the foot. With ageing or prolonged repetitive overuse, the absorbability of the plantar fascia and fat pad might decrease, and this might explain why master runners are more susceptible to have plantar fasciitis compared with other types of RRMIs. A prospective study also observed that more experienced runners were more prone to sustain foot injuries;[12] however, this conclusion was classified as limited evidence in a previously published systematic review aimed to identify determinants of lower extremity running-related injuries.[5]

Studies have reported that patellofemoral syndrome is the most common RRMI among runners;[2,9,27,29] although our review revealed a different picture. Patellofemoral syndrome did not present as the highest incidence or prevalence rates of general RRMI, and only two articles reported this injury.[10,26] We take note that one study used the term 'runner's knee' to describe injuries around the knee region.[24] However, 'runner's knee' has been used by some authors to refer to patellofemoral syndrome[14,49,50] or iliotibial band syndrome.[51,52] Thus, we are not sure whether the authors referred to patellofemoral syndrome or iliotibial band syndrome in their study.[24] We also suggest the term 'runner's knee' should be avoided to describe the injury around the knee area until there is consensus on the exact pathology that we refer to. Based on the results of this review, the most common RRMI around the knee region is the patellar tendinopathy, which the sports medicine community generally agree is the 'jumper's knee'.[53]

Patellofemoral syndrome was common during ultra-marathon races[27-29] and it was the third most prevalent RRMI among the ultra-marathoners. The most frequently cited aetiology for the patellofemoral syndrome is the abnormal patellar tracking plus high compressive loads generated by the quadriceps femoris muscle contraction that lead to an increased stress on the joint.[54,55] The repetitive contractions of the quadriceps femoris during running may contribute to the high compressive loads in the patellofemoral joint favouring the development of patellofemoral syndrome. A prospective study that enrolled marathon runners concluded that participating in a marathon race for the first time, use of medication, and running few kilometres per week were considered to be risk factors for the development of patellofemoral syndrome.[4] Another prospective study showed that an increase of distance (kilometres) and the number of hours of training per week were considered to be protective factors against knee injuries in marathon runners.[12] This was classified as strong evidence in a systematic review about this topic.[5]

Ankle dorsiflexors tendinopathy is common among ultra-marathon runners during a race.[28,29] The condition is not common among non-ultra-marathon runners and may indicate that this RRMI may be specific to ultra-marathon runners only. This tendinopathy has been quoted as an 'ultra-marathoner's ankle' in one ultra-marathon study.[29]

Most of the studies in this systematic review presented a moderate risk of bias. One of them had achieved a score of 4 out of possible score of 9.[26] Although most of the studies have a clear definition of RRMIs, the definitions always differ between studies. For instance, in one study, the injury was defined as 'injuries sufficiently severe to impair their performance'[28] while for another study, RRMIs were defined as 'injuries that markedly hampered running training or competition for at least one week.'[10] It should be noted that since 2007, it has been suggested in the sports medicine community that a standard RRMI definition should be adopted[5] but, to our knowledge, there is no consensus about the most appropriate definition for an RRMI. All articles included in this review described the type of runners (e.g., ultra- marathoners[27-29]) or their characteristics of training (e.g., running at least five times per week[23]), or race participation (runners of a 10 km race[25]). Different definitions of RRMIs, as well as a difference in runners' characteristics, hampers the possibility of pooling the data for a meta-analysis or for making a meaningful comparative analysis of the incidence or prevalence rates of RRMIs.[5,21,56]

In terms of the participants, only one study performed a random sample selection[25] and two studies sampled the entire target population of runners.[28,29] There are only three prospective studies that could enable the assessment of the loss to follow-up criterion,[10,23,24] and all of them fulfilled this criterion, which indicated a lower risk of bias in these studies.[57] One study did not collect the information of injuries directly from runners[28] and this can introduce some degree of bias.[58] Five studies used the same mode of injuries data collection for all runners,[10,24,25,27,29] and three studies utilised a mixed mode of data collection (i.e., data collected whilst observing a race could be either transmitted for assessment via e-mail or hard copy,[26] by telephone or verbally,[23] or data could be collected through interviewing runners, and health professionals such as physicians or physical therapists[28]). Standardisation of the data collection for all runners would reduce the risk of bias on these studies.[58,59]

Studies that aimed to register or evaluate RRMIs should describe how the diagnosis was made. The RRMI should best be diagnosed properly by medical professionals to minimise the risk of bias or misinterpretation of the diagnosis. All studies described the injury collection procedure and only two studies did not have a diagnosis made by medical doctors/professionals.[25,26] Four studies used a running diary or a questionnaire to register RRMIs by the runners themselves.[10,24-26] This self-reported information about an RRMI may only represent what the runners think about their injuries, and the injuries themselves might be either under- or overestimated.

Running injuries are primarily overuse injuries that occur due to the overloading of the musculoskeletal structures[15,30] caused by repetitive microtrauma over a long period of time.[60] Thus, a long follow-up period is necessary to capture all the possible RRMIs and the response relationships with training. Three incidence rate studies (two prospective[10,23] and one clinical trial[24]) were conducted for at least six months and fulfilled this criterion. Retrospective studies are more prone to recall bias.[56,61,62] We consider a 12-month period to be acceptable, and a study has indicated that the recall bias within this period is around 12%.[62]

In order to compare the incidence or prevalence rates of RRMIs among different studies, it is necessary to express these injury rates in a comparable or common unit.[5] Some studies with runners as the subjects reported RRMI rates by using the number of injuries per 1,000 hours of exposure to running[7-12] and this is more appropriate because the amount of exposure to the load (running) may influence the development of musculoskeletal injuries.[63] Among the eight articles, only two of them stated the overall incidence ratio of RRMIs per 1,000 hours of exposure to running[10,24] and no study stated the incidence or prevalence ratio of each RRMI. We suggest that future studies should standardise the expression of RRMI data by the ratio of the number of injuries per hour of exposure to running. This would enable comparison or pooling of data for meta-analysis.[64] In addition, future studies should be conducted to determine a consensus about the definition of RRMIs, as well as aim to identify the main RRMIs in different types of runners (e.g., ultra-marathoners, marathoners, elite, recreational, race runners, etc.).

Limitations

Electronic searches were conducted in the main databases related to the sports injuries field. However, it is possible that eligible articles have been published in journals that are not indexed in any of the searched databases.

Conclusion

The most frequent general RRMIs reported by studies were medial tibial stress syndrome, Achilles tendinopathy, and plantar fasciitis. For runners who participated in ultra-marathon races that ranged from 5 to 8.5 days, Achilles tendinopathy and patellofemoral syndrome were the two most common RRMIs. These lower limb injuries are predominately located at the foot, ankle, lower leg, or the knee.

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